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DATE: Monday, March 22, 2004

Hide?	Set Name	Query	Hit Count
		DB=USPT; PLUR=YES; OP=ADJ	
☐	L8	L7 and (conveyer or conveyor)	147
☐	L7	134/$.ccls. and (ultraso$ or megaso$) and (nozzle or jet or spray$)	1264
☐	L6	L5 and 134/$.ccls.	1
☐	L5	L4 and clean$	26
☐	L4	hard disk drive head	154
☐	L3	L1 and (hard disk)	3
☐	L2	L1 and hard disk	3
☐	L1	134/1.ccls or 134/184.ccls.	443

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DATE: Monday, March 22, 2004

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	DB=USPT; PLUR=YES; OP=ADJ		
☐	L12	L11 and (ultraso$ or megaso$)	18
☐	L11	134/902.ccls. and (belt with convey$)	57
☐	L10	L8 and (power or frequency)	57
☐	L9	L8 and 134/$.ccls.	0
☐	L8	(ultraso$ or megaso$) with shockwave	82
☐	L7	(ultraso$ or megaso$) with shochwave	0
☐	L6	134/184.ccls. and shockwave	0
☐	L5	L4 and cavitat$	0
☐	L4	6497240.pn. or 6619301.pn.	2
☐	L3	L2 and cavitat$	1
☐	L2	5975098.pn.	1
☐	L1	5975098.pn	0

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L12: Entry 12 of 18 File: USPT May 5, 1998

DOCUMENT-IDENTIFIER: US 5745946 A
**** See image for Certificate of Correction ****
TITLE: Substrate processing system

Brief Summary Text (7):
A wet processing system such as a scrubber, wherein both sides of a wafer are scrubbed comprises several distinct stations or modules. Each module is typically enclosed in a box-like structure which comprises the appropriate processing apparatus for that station. For example, a scrubber, wherein both sides of a wafer are scrubbed may comprise a load or send station, one or more scrub stations, a spin rinse and spin dry station, and an output station. The load or send station typically comprises a platform for holding the cassette, an elevator for lowering and raising the cassette, and a sensor for sensing the presence of a wafer. Additionally, the load station may comprise sprayers to spray the wafers with filtered, deionized water (D.I. water) to keep them wet while they are awaiting processing. This is necessary where the previous operation, such as chemical mechanical polishing, leaves wet contamination (e.g., the slurry mixture) on the wafers, which, if dried, would be virtually impossible to remove. The scrub station typically comprises one or more brushes, wheels which grip and turn the wafer by its side during scrubbing, and sprayers or nozzles for dispensing chemicals. The spin station typically comprises a nozzle for a final water rinse, a spinner for spin drying, and a lamp to provide heat assisted drying. The spin station may also comprise a nitrogen blow off in addition to or in place of the heat lamp to assist drying. Finally, an output station comprises a platform for holding the cassette of cleaned and dried wafers. Additionally, one or more types of wafer transport mechanism, such as rollers, belt conveyors, robotic arms, etc., are provided within and between the stations to transport wafers within and between the stations. The system also comprises numerous sensors to detect the presence of a wafer, and to determine the location of the flat of the wafer, if desired. Often, the portion of the system up to and including the final scrub station is considered the "dirty" side of the system, while the portion after the cleaning stations, including the output station is considered the "clean" side of the system because the wafer has already been processed through a first and a second scrub operation. During the spin rinse and spin dry, the water is typically lowered into a cup-shaped structure having a vacuum pulled from the bottom, so that liquid spun off is not directed upward but rather is directed outward and downward. To maintain cleanliness, the top of the dry station is typically open to the fabrication area's overhead laminar flow, or may have its own laminar flow unit to maintain the cleanliness of the wafers. Typically, each module has one or more openings in the bottom portion to allow for connections to the appropriate facilities.

Brief Summary Text (9):
As a wafer is processed, it is passed from one station to next. For example, the sender sends a wafer to the first brush station where it is scrubbed. As mentioned above, the wafer may be sent by a conveyor belt type mechanism having belts which contact the wafer from the underside. As the belts turn, they move the wafer out of the cassette and toward the next processing station. Typically, the entire mechanism itself moves to bridge the gap between the two stations and pass the wafer to another conveyor belt mechanism in the next station. Alternatively, other similar mechanisms may be used. One problem that occurs in transporting the wafer is that as the wafer is wet, it may drip, causing fluid to flow in the interface between the two processing modules. Additionally, the transport mechanism may convey and drip liquid between the modules. The contribution from the transport mechanism may be minimized by, as described above, moving the entire transport mechanism to bridge the gap between stations when conveying a wafer, and then moving it away from the gap at all other times. However, this does not entirely eliminate dripping between stations from the conveyor mechanism. Additionally, this method may not be as convenient as placing a conveyor permanently between stations. Since many of the fluids may contain contamination from the wafers, or dissolved cleaning chemicals, as the dripped material dries, flaking is a problem. This increases the level of contamination, and may cause damage to the system. To remedy this, a thin flexible piece of a plastic type material is placed over the interface of the two enclosures. This method is not entirely satisfactory as some liquid may get underneath the plastic and between the two enclosures. Bacteria can easily grow in this still liquid and eventually get on the wafers as contamination. Additionally, the plastic may move or be ripped, etc.

Detailed Description Text (3):
FIG. 1 A shows a block diagram of a wafer scrubber, wherein both sides of a wafer are scrubbed using the methods and apparatuses of the present invention. As shown, a wafer 101a exits cassette 111 from load station 1 10. The wafer 101a will be denoted as 101a, 101b, etc. as it proceeds through the stations or modules of the scrubber, to illustrate the process flow. It will be appreciated that in operation, each of the stations may be processing a different wafer at the same time. Although the present invention is described in conjunction with a semiconductor wafer, it will be appreciated that any similarly shaped, i.e. generally flat substrate, may be processed by the methods and apparatuses of the present invention. Further, it will appreciated that reference to a wafer or substrate may include a bare or pure semiconductor substrate, with or without doping, a semiconductor substrate with epitaxial layers, a semiconductor substrate incorporating one or more device layers at any stage of processing, other types of substrates incorporating one or more semiconductor layers such as substrates having semiconductor on insulator (SOI) devices, or substrates for processing other apparatuses and devices such as flat panel displays, multichip modules, etc. After exiting cassette 111, the wafer 101 a enters first brush station 120 where, as shown by wafer 101b, it is scrubbed on the top and bottom sides by brushes 121a and 121b. The wafer next enters second brush station 130, and as shown by wafer 101c, is scrubbed by brushes 131a and 131b. Next, the wafer enters spin dry station 140 where it is rinsed with D.I. water and, additionally if desired, treated with megasonic energy to further remove particles. Next, the wafer 101d is spun dry while being heated with a heat

lamp (not shown in FIG. 1A). After the spin dry operation, the wafer is sent to output station 150 and loaded in cassette 151 as shown by wafer 101e.

Detailed Description Text (14):
FIG. 3A shows a side view of brush stations 120 and 130. As shown, both brush stations 120 and 130 are disposed within a single enclosure 301. Also as shown, a divider 302 separates the two brush stations. In a currently preferred embodiment, enclosure 301 and divider 302 are made of polycarbonate. As can be seen, a wafer may be transported on transport mechanism 118, which is a conveyor belt-type mechanism in a currently preferred embodiment. Tunnel 119 extends through the station 110/station 120 interface, so that a wafer may be transported from load station 110 to first brush station 120 without liquid from either the wafer or the transport mechanism 1 18 dripping between the two stations. Tunnel 119 will be discussed in more detail in conjunction with FIG. 4. In the prior art, a transport mechanism does not extend across the two modules, since this would lead to constant leakage between the two. In the present invention, by virtue of tunnel 119, the mechanism 118 can be permanently disposed within the tunnel to transport wafers between modules without worry of leakage in between the modules. In this way, the complexity of the system is reduced since a mechanism for moving the entire transport mechanism 118 back and forth between modules is not required. In a similar manner, transport 128 extends through an opening 129 in divider 302 to pass the wafer into brush station 130. No tunnel such as tunnel 119 is required in divider 302 since the two brush stations are already in a single enclosure. Similarly, after the brushing in brush station 130 the wafer is passed via transport mechanism 128 through tunnel 139 to the spin rinse dry station 140 of FIGS. 1A and 1 B. In the brush stations 120 and 130, components which cannot be contacted by fluids, such as the motors to turn the brushes, wafer conveyors, etc., are encased in, for example, plastic. As described earlier, fluid which collects on the covers may flow along the sides of the system. This and other fluids from the process drain off of bottom plate 315 into drain 316.

Current US Cross Reference Classification (2):
134/902

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L3: Entry 1 of 1 File: USPT Nov 2, 1999

DOCUMENT-IDENTIFIER: US 5975098 A

**** See image for Certificate of Correction ****

TITLE: Apparatus for and method of cleaning substrate

Brief Summary Text (23):

When the high-pressure rinsing nozzle swings in this manner, a bubbling-induced cavitation effect is created inside the rinsing liquid which is supplied onto a surface of the substrate. This further enhances the cleaning ability.

Brief Summary Text (54):

When high-pressure rinsing is performed while swinging as in the fourth, the tenth, the fifteenth and the twenty-second inventions in particular, a bubbling-induced cavitation effect is created inside the rinsing liquid which is supplied onto a surface of the substrate. This further enhances the rinsing ability.

Detailed Description Text (64):

Further, swinging scanning as described above moves the high-pressure rinsing jet J in injected ultrasonic rinsing liquid, which in turn creates a bubbling-induced cavitation effect inside the rinsing liquid which is supplied onto the surface of the substrate. This further enhances the rinsing effect.

Detailed Description Text (114):

During combined rinsing according to the second preferred embodiment, as shown in FIG. 14, the jet J of the high-pressure rinsing is jetted out into the ultrasonic rinsing liquid F is injected from the ultrasonic rinsing nozzle 10. If an optional position within the substrate 1 is noted, the noted position is subjected to the high-pressure rinsing jet J from the high-pressure rinsing nozzle 20B, first, as the substrate is transported in the direction X. As there is a flow of the ultrasonic rinsing liquid F at the destination of the jet J, a foreign matter which is removed by high-pressure rinsing is washed away by the flow of the ultrasonic rinsing liquid F without adhering to the surface of the substrate 1 again. In addition, the high-pressure rinsing jet J moves within the ultrasonic rinsing liquid F as the high-pressure rinsing nozzles 20A and 20B are swung, and therefore, a bubbling-induced cavitation effect is created inside the rinsing liquid which is supplied onto the surface of the substrate. This further enhances the rinsing effect.

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DATE: Monday, March 22, 2004

Hide?	Set Name	Query	Hit Count
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☐	L10	L8 and (power or frequency)	57
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☐	L7	(ultraso$ or megaso$) with shochwave	0
☐	L6	134/184.ccls. and shockwave	0
☐	L5	L4 and cavitat$	0
☐	L4	6497240.pn. or 6619301.pn.	2
☐	L3	L2 and cavitat$	1
☐	L2	5975098.pn.	1
☐	L1	5975098.pn	0

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L6: Entry 1 of 1 File: PGPB Aug 16, 2001

DOCUMENT-IDENTIFIER: US 20010013355 A1

TITLE: Fast single-article megasonic cleaning process for single-sided or dual-sided cleaning

Abstract Paragraph:
A fast single-article megasonic cleaning system (200) is used to clean substrates (such as semiconductor wafers, flat panel display glass, etc.) at frequencies of 400 kHz-20,000 kHz or higher. The technique provides a single-wafer cleaning process that reduces the cleaning time from the 10-20 minutes typical of the prior art to 15-60 seconds. The system utilizes concentrated megasonic energy on one wafer (90) to dramatically reduce cleaning time. The system uses a transducer (210) or a pair or transducers (210a, 210b) parallel to the substrate (90) to be cleaned where the transducer area is more than about 40% of the substrate area. Two alternate configurations are disclosed, one utilizing a horizontal wafer arrangement and the second utilizing a vertical wafer arrangement. The latter requires a smaller floor area. Preferred spacings between the wafer and the transducer, preferred transducer power and intensity, preferred overflow flow rate of fluid medium (220) (which may be deionized water), effective cleaning times, and process temperature are disclosed.

Current US Classification, US Primary Class/Subclass:
134/1.3

Current US Classification, US Secondary Class/Subclass:
134/184

Current US Classification, US Secondary Class/Subclass:
134/902

Summary of Invention Paragraph:
[0002] This invention relates generally to surface cleaning of articles such as semiconductor wafers, flat panel display glass, hard disk drives and heads, and the like to remove particulate and chemical contaminants. In particular, the invention relates to megasonic cleaning of oxide, metallic, or polymer films following planarization (Chemical Mechanical Polishing, CMP) and other polishing processes.

Summary of Invention Paragraph:
[0003] Wafer cleaning (especially megasonic wafer cleaning) is used before and after most basic semiconductor manufacturing processes such as: pre-oxidation, pre-CVD, pre-EPI, post-ASH, and post-CMP. Megasonic cleaning is

used in every major semiconductor fabrication facility today. The majority of these processes are batch processes. A paper by G. W. Gale and A. A. Busnaina, "Removal of particle contaminations using ultrasonics and megasonics: a review", Particulate Science and Technology, vol. 13, pp. 197-211 (1995) reviewed the background art. Some megasonic nozzles are being marketed for rinsing purposes after contact cleaning processes. Such nozzles are available from Dainippon Screen Mfg. Co. of Kyoto, Japan; Solid State Equipment Corp. of Fort Washington, Pa., and others. However, available megasonic nozzles are not sufficiently effective in cleaning wafers because of the low power, the low flow rate, and their small relative size (a small ratio of transducer area to wafer area). No effective, fast, non-contact, single-wafer cleaning process exists today. One company (Verteq, Inc., of Santa Ana, Calif.) has produced a megasonic single-wafer cleaning system called "Goldfinger." The Goldfinger system uses one transducer above a rotating wafer, with a meniscus between the wafer and the transducer. Single-wafer megasonic cleaning methods and apparatus are described in U.S. Pat. Nos. 5,090,432, 5,148,823, and 5,286,657 to Bran.

Summary of Invention Paragraph:
[0004] Most megasonic cleaning tanks are employed in batch cleaning processes that may take, on average, between 10 and 20 minutes for cleaning a batch of about 25 wafers. The long cleaning time has been a major problem and a source of low production output. In addition, the majority of other semiconductor manufacturing processes are single-wafer processes. Therefore, use of a batch process for cleaning creates bottleneck and other wafer-handling problems associated with integrating the vast number of single-wafer manufacturing processes with batch cleaning processes.

Summary of Invention Paragraph:
[0005] Megasonic single-wafer cleaning systems using a relatively small transducer above a rotating wafer with a meniscus between the wafer and the transducer have been extensively tested by users and have not been proven sufficiently effective. Therefore they have not been generally adopted for demanding cleaning applications such as post-Chemical-Mechanical-Polishing (CMP) cleaning in the semiconductor and other industries. Reasons for the insufficient effectiveness include the facts that the megasonic energy delivered per square centimeter of the wafer is very small in such systems and that the megasonic energy is delivered for a fraction of the time during the duration of the cleaning process. These limitations diminish the cleaning effectiveness of the process.

Summary of Invention Paragraph:
[0006] Accordingly, several objects and advantages of the present invention are to provide surface cleaning of semiconductor wafers, flat-panel-display glass, or hard-disk-drive disks and heads effectively in a very short time, with or without the use of chemicals other than deionized (DI) water. The process of the present invention has improved effectiveness and efficiency in comparison with all of the cleaning process products of the prior art. The cleaning system of the present invention, which is compact in size and process, puts an end to all the problems associated with batch cleaning processes. The improvements are accomplished in part by providing a new apparatus and process that utilizes a different design geometry than those commonly used in megasonic cleaning tanks. The improvements also involve system and process specifications such as the relative size of the transducer

area with respect to the substrate to be cleaned (e.g., semiconductor wafers), the distance between wafer and transducer, the transducer power and intensity, the overflow flow rate, the cleaning time, and the process temperature. A particular advantage of the present invention is that maximum megasonic energy is delivered to every square centimeter of the wafer area for the entire duration of the cleaning process without the need for wafer rotation. Two alternate configurations are presented; one uses a smaller foot print to reduce the floor area that the tool will occupy. Experimental data shows that the cleaning efficiency obtained using this process (in less than one minute, and often as little as 15 seconds) is better than that of a batch megasonic cleaning after 13 minutes. A key factor is in the application of the same amount of megasonic energy to one wafer in the present invention as is used in cleaning 25 wafers in methods of the prior art. Still further objects and advantages will become apparent from a consideration of the ensuing description and accompanying drawings.

Summary of Invention Paragraph:
[0007] With the recent trend by semiconductor manufacturers of adopting single-wafer processes in manufacturing, the improved process of the present invention is expected to reduce cleaning and manufacturing time and is expected to solve the bottleneck and other wafer-handling problems associated with integrating the vast number of single-wafer manufacturing processes with cleaning processes.

Summary of Invention Paragraph:
[0008] As pointed out above, most batch cleaning megasonic cleaning processes take, on average, 10-20 minutes time for cleaning a batch of about 25 semiconductor wafers, hard-drive disks, or flat-panel-display glass substrates. Most attempts by various equipment manufacturers at cleaning a single wafer in a short time using a megasonic process have not been successful. There is an immediate need for an effective, fast, non-contact, single-wafer cleaning method especially for post-chemical-mechanical-polishing (post-CMP) cleaning applications.

Brief Description of Drawings Paragraph:
[0009] FIG. 1. Schematic cross-sectional elevation view of a typical batch megasonic cleaning apparatus of the prior art.

Brief Description of Drawings Paragraph:
[0011] FIG. 2. Schematic cross-sectional elevation view of a fast single-wafer megasonic cleaning apparatus made in accordance with the present invention.

Brief Description of Drawings Paragraph:
[0012] FIG. 3. Schematic cross-sectional elevation view of a second embodiment of a fast single-wafer megasonic cleaning apparatus made in accordance with the present invention.

Brief Description of Drawings Paragraph:
[0014] FIG. 5. Bar chart illustrating removal efficiency of alumina particles using the present invention, compared with removal efficiency using a method and apparatus of the prior art for various cleaning times.

Brief Description of Drawings Paragraph:

[0015] FIG. 6. Bar chart illustrating particle counts of alumina particles before and after deposition, and after cleaning by use of the present invention in comparison with particle counts with a prior art method and apparatus.

Brief Description of Drawings Paragraph:
[0016] FIG. 7. Schematic cross-sectional view of a single-wafer megasonic cleaning apparatus having a pair of transducers mounted on either side of a substrate in accordance with the present invention.

Brief Description of Drawings Paragraph:
[0017] FIG. 8. Schematic cross-sectional view of a horizontal embodiment of a single-wafer megasonic cleaning apparatus having a pair of transducers mounted on either side of a substrate in accordance with the present invention.

Detail Description Paragraph:
[0018] A megasonic transducer is used to clean substrates (such as semiconductor wafers) at frequencies larger than 400 kHz-20,000 kHz or higher. The technique introduces a single-wafer cleaning process that reduces the cleaning time from 10-20 minutes to the present invention's cleaning time of 15-60 seconds. The process of the present invention cleans a wafer in less than one minute without utilizing any chemistry other than deionized (DI) water. The use of chemistry such as SC1 (5-40 H.sub.2O:1-2H.sub.2O.sub.2:1NH.sub.4OH) should reduce the current cleaning time. Megasonic cleaning provides a very small acoustic boundary layer (on the order of 0.59 microns for 900 kHz) which exposes contaminants, such as submicron particles, to the fluid's acoustic stream and facilitates their removal. It has been shown that the new process is capable of completely removing particles as small as 100 nanometers (current surface detection limits). The detailed description below indicates why current megasonic equipment used today is not capable of matching the current removal efficiency provided by this invention using the same cleaning time. The semiconductor industry is quickly moving toward single-wafer processing. Today more than 80% of wafer processing is single-wafer based. This process eliminates the need for batch cleaning processes as well as reducing the time per wafer to less than 60 seconds. The cleaning time depends on the type of contaminant to be removed. For instance, silica particles can be completely removed in 15 seconds while alumina particles may need 30 seconds or more time when using DI water.

Detail Description Paragraph:
[0019] The technique is very effective when utilizing only DI water. The technique becomes even more effective when coupled with basic or acidic chemistry (depending on the substrate to be cleaned).

Detail Description Paragraph:
[0020] Most megasonic cleaning processes used extensively in wafer cleaning by the semiconductor, hard drive, and flat-panel display industries are batch cleaning processes that typically take between 10 and 20 minutes, on average, (for 25 wafers cleaned simultaneously in a batch cleaning tank). FIG. 1 shows a schematic cross-sectional elevation view of a typical batch megasonic cleaning apparatus 10 of the prior art. A multiplicity 20 of wafers to be cleaned is held in a cassette 30 which holds wafers 20 in a parallel

arrangement inside container 40. Container 40 also holds a liquid cleaning medium 50, which has a liquid surface 55. A megasonic transducer 60 transfers megasonic energy 70 through cleaning medium 50 to the surfaces wafers 20.

Detail Description Paragraph:
[0021] FIG. 1A shows a magnified detail of a portion of FIG. 1, illustrating schematically by flow lines 100 the slower fluid flow that occurs near the surface of an individual wafer 90 in such a batch process, where the liquid medium flows between wafers. Comparisons between the results obtained using prior art apparatus similar to FIG. 1 as compared with results using the methods and apparatus of the present invention are described below. Most earlier attempts by various equipment manufacturers at cleaning a single wafer using megasonic cleaning for a short time have not been successful.

Detail Description Paragraph:
[0022] The process of the present invention is capable of accomplishing cleaning in a very short time without the use of any chemicals. This is accomplished by a new process that requires a different geometry and by controlling and using specific process specifications and parameters such as the relative size of the transducer area with respect to the substrate to be cleaned (e.g., semiconductor wafers), distance between wafer and transducer, transducer power and intensity, overflow flow rate, cleaning time, and process temperature. The process steps and the parameters controlled are presented below.

Detail Description Paragraph:
[0023] Two alternate configurations for the apparatus are presented in FIGS. 2 and 3. FIG. 2 shows a schematic cross-sectional elevation view of a first fast single-wafer megasonic cleaning apparatus 200 made in accordance with the present invention. FIG. 3 shows a schematic cross-sectional elevation view of a second embodiment of a fast single-wafer megasonic cleaning apparatus 200 made in accordance with the present invention. The second embodiment shown in FIG. 2 uses a smaller footprint to reduce the floor area the tool occupies. In both FIGS. 2 and 3, the apparatus 200 includes a container 205 for holding single wafer 90 to be cleaned and for holding the liquid cleaning medium 220, and a megasonic transducer 210 disposed to face the surface of single wafer 90 to be cleaned. Megasonic energy is directed 270 from megasonic transducer 210 toward the surface of single wafer 90 to be cleaned. The apparatus is arranged so that liquid cleaning medium 220 has a free liquid surface 250, and the liquid flow is shown in FIGS. 2 and 3 by flowlines 245 within container 205, by inlet flowlines 240, and by overflow outlet flowlines 260, showing that the liquid cleaning medium 220 overflows the container.

Detail Description Paragraph:
[0024] Megasonic transducer 210 has a transducer area between 40% and 100% of the area of the individual substrate 90 to be cleaned. The substrate 90 is positioned parallel to the transducer 210 and spaced apart from megasonic transducer 210 by a predetermined distance. A flow of liquid medium 220 is maintained between the substrate and the transducer, while applying megasonic energy at a suitable frequency of at least 400 kilohertz (kHz). Megasonic transducer 210 may be a conventional piezoelectric transducer capable of operating at a suitable frequency. A conventional supply of electrical energy at a suitable frequency is provided to drive the megasonic transducer 210.

The megasonic energy applied has a maximum power of at least 400 watts. The megasonic energy applied should be between 20% and 100% of the maximum power and preferably between 50% and 100% when cleaning with DI water alone. The transducer 210 should have a total input intensity (power per unit transducer area) of at least four watts per square centimeter.

Detail Description Paragraph:
[0025] For using a transducer area of less than 100% of the area of the individual substrate 90, a relative motion between the individual substrate and the transducer is preferably provided in a direction parallel to the substrate, while performing the fluid-flowing and the megasonic-energy-applying step. The transducer should face at least 40% of the surface area of individual substrate 90 to be cleaned. That is, the major area of the transducer that faces the substrate 90 should have an area that is at least 40% of the major area of one side of the substrate 90 to be cleaned. The distance between the transducer and the individual substrate 90 should be in the range from 1% to 80% of the maximum diameter of substrate 90, or at least a minimum of 1 micrometer or larger away from the substrate. The distance between transducer 210 and the individual substrate 90 is preferably maintained in a range from 1 micrometer to 160 millimeters.

Detail Description Paragraph:
[0026] The fluid flowing in the space between the substrate and the transducer is moved at a fluid flow rate sufficient to carry particles away from the substrate before they redeposit on the substrate. The fluid medium 220 flowing in the space between substrate 90 and the transducer 210 is preferably moved at a rate suitable to replace the fluid in the cleaning container 205 in less than or equal to one minute. The overall method for megasonic cleaning of individual substrates 90 with this apparatus thus comprises the steps of: providing a megasonic transducer 210 having a transducer area between 40% and 100% of the area of the individual substrate 90 to be cleaned; disposing the individual substrate 90 substantially parallel to and spaced apart from transducer 210 by a predetermined distance, thereby defining a space between substrate 90 and transducer 210; and flowing a fluid through the space between substrate 90 and transducer 210, while applying megasonic energy to the megasonic transducer 210 at a frequency of at least 400 kilohertz (kHz). Optionally, the method can also include the further step of providing relative motion between individual substrate 90 and transducer 210 in a direction substantially parallel to substrate 90, while performing the fluid-flowing and energy-applying step. The fluid-flowing step is preferably performed at a fluid flow rate sufficient to carry particles away from the substrate before they redeposit on the substrate. Preferred process temperatures are in the range 20.degree. C. to 70.degree. C.

Detail Description Paragraph:
[0027] In an alternate embodiment two megasonic transducers 210a, 210b can be used to clean both sides of substrate 90, as shown for a vertical embodiment in FIG. 7. Substrate 90 is positioned parallel between transducers 210a, 210b and spaced apart from them by a predetermined distance. Both transducers 210a, 210b, or at least their active surfaces 210a', 210b' can be immersed in fluid 220 along with substrate 90. Transducers 210a, 210b are preferably mounted on opposite walls 205a, 205b of container 205' in a fixed position, as shown in FIG. 7. Providing energy from both sides facilitates cleaning edges as well as both sides of substrate 90.

Detail Description Paragraph:
[0033] Fluid 220 flows in the space between substrate 90 and transducers 210a, 210b at a fluid flow rate sufficient to carry particles away before they redeposit on substrate 90. For example, the fluid flows at a rate to replace fluid 220 in cleaning container 205' in less than or equal to one minute.

Detail Description Paragraph:
[0035] Experimental data show that the cleaning efficiency obtained using the present invention process (in less than one minute, as little as 15 seconds) is better than that of a batch megasonic cleaning after 13 minutes. One key factor in achieving this improvement using the present invention is in applying to one wafer the same amount of megasonic energy used in a batch process for cleaning 25 wafers.

Detail Description Paragraph:
[0036] FIG. 4 is a bar chart illustrating removal efficiency of silica particles using apparatus and methods of the single transducer embodiment of the present invention. Vertical axis 400 represents particle removal efficiency, and cleaning time in seconds is plotted along horizontal axis 410. Bar 420 shows the efficiency of removing 0.15 micrometer silica particles with 15 sec. cleaning. Bar 430 shows the efficiency of removing 0.15 micrometer silica particles with 30 sec. cleaning. Bar 440 shows the efficiency of removing 0.15 micrometer silica particles with 45 sec. cleaning.

Detail Description Paragraph:
[0037] FIG. 5 is a bar chart illustrating removal efficiency of alumina particles using the single transducer embodiment of the present invention, compared with removal efficiency using a method and apparatus of the prior art for various cleaning times. In FIG. 5, vertical axis 500 represents particle removal efficiency, and the processes used are plotted along horizontal axis 510. Bar 520 depicts the efficiency of removing alumina particles with 10 min. cleaning using a batch megasonic process of the prior art. Bar 530 depicts the efficiency of removing alumina particles with 20 min. cleaning using a batch megasonic process of the prior art. Bar 540 depicts the efficiency of removing alumina particles with 1 min. cleaning using the fast single-wafer megasonic process of the present invention.

Detail Description Paragraph:
[0038] FIG. 6 is a bar chart illustrating particle counts of alumina particles before and after deposition, and after cleaning by use of the single transducer embodiment of the present invention in comparison with particle counts with a prior art method and apparatus. The number of particles larger than 0.1 micrometer is represented by vertical axis 600 of FIG. 6. The horizontal axis 610 represents the process used. Bars 620 represent the number of particles measured before deposition, bars 630 the number of particles after deposition, and bars 640 the number of particles after cleaning. Groups 650 show the results due to cleaning by a batch megasonic cleaning process of the prior art for 10 min. Groups 660 show the results due to cleaning by batch megasonic cleaning process of the prior art for 20 min. Groups 670 show the results due to cleaning by fast single-wafer cleaning process of the present invention for 1 min.

Detail Description Paragraph:
[0039] The invention provides a megasonic cleaning process capable of accomplishing cleaning of a single wafer or other substrate in a very short time without the use of any chemicals other than de-ionized water. Apparatus specially adapted for performing the single-wafer megasonic cleaning process has improved efficiency of particle removal. Apparatus made in accordance with the invention is applicable to cleaning processes that require very clean surfaces, especially semiconductor wafer and photomask cleaning processes. The methods of the invention can be used to improve cleanliness of semiconductor wafers, thus increasing the yields and lowering the costs of the semiconductor products formed on the wafers. Similar apparatus suitably arranged can be used for cleaning other planar articles, such as glass or quartz flat panel display substrates, hard-disk-drive disks, and heads.

Detail Description Paragraph:
[0040] While the invention has been shown and described in connection with a preferred embodiment, various changes may be made therein without departing from the spirit and scope of the invention as defined in the appended claims. For example, individual cleaning stations as described herein may be combined together in a cluster in arrangements other than those shown. The order of steps of the processes may, of course, be varied.

CLAIMS:

1. A method for megasonic cleaning a substrate, comprising the steps of: a) providing a container; b) providing a first megasonic transducer with a first active surface in said container; c) disposing a substrate in said container substantially parallel to and spaced from said first transducer; d) flowing a fluid through said space between the substrate and said first transducer; e) immersing the wafer with said fluid in said container; and f) applying energy to said first megasonic transducer.

17. The method as recited in claim 12, wherein said megasonic transducers provide energy to clean both sides and edges of the substrate.

18. The method as recited in claim 1, wherein said fluid comprises one of deonized water, dilute RCA cleaning solution and dilute citric acid solution.

23. A method for megasonic cleaning a substrate, comprising the steps of: a) providing a container comprising a first megasonic transducer with a first active surface, wherein said first magasonic transducer is held in a fixed position in said container; b) disposing a substrate in said container substantially parallel to and spaced from said first active surface; c) flowing a fluid through said space between the substrate and said first active surface; and d) applying energy to said first megasonic transducer.

24. A method for megasonic cleaning a substrate, comprising the steps of: a) providing a first megasonic transducer with a first active surface; b) providing a second megasonic transducer with a second active surface facing said first active surface and parallel thereto; c) disposing a substrate between said first surface and said second surface to provide a first space between the substrate and said first surface and a second space between the

substrate and said second surface; d) flowing a fluid through said first space and through said second space; and e) applying energy to said first megasonic transducer and to said second megasonic transducer to clean two sides of the substrate.

36. The method as recited in claim 24, wherein said megasonic transducers provide energy to clean edges of the substrate.

37. The method as recited in claim 24, wherein said fluid comprises one of deonized water, dilute RCA cleaning solution and dilute citric acid solution.

41. An apparatus for megasonic cleaning a substrate, comprising: a container for immersing a substrate in a fluid; a first megasonic transducer with a first active surface in the fluid in said container for providing energy to clean the immersed substrate placed substantially parallel to and spaced from said first active surface.

49. The apparatus as recited in claim 41, further comprising a second megasonic transducer with a second active surface in said tank, wherein said second active surface faces said first active surface and is substantially parallel to and spaced from said first active surface for cleaning both sides of a substrate and edges of a substrate placed between said first active surface and said second active surface.

55. The apparatus as recited in claim 41, wherein said fluid comprises one of deonized water, dilute RCA cleaning solution and dilute citric acid solution.